

Effect of Arresters on Erosion in Economizer Zone and its Analysis

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Abstract Thermal Power Stations all over the world are facing the problem of boiler tube leakage frequently. The consequences of which affects the performance of power plant and huge amount of money loss. It was also found from the trends of failure that the economizer is the zone where the leakages are found more. The maximum number of cause of failure in economizer unit is due to flue gas erosion. The authors in this paper have attempted to suggest a probable solution for reduction of erosion in economiser zone and its analysis using CFD tool. The past failure details reveals that erosion is more in U-bend areas of Economizer Unit because of increase in flue gas velocity near these bends. Horizontal Arresters were provided on the way of flue gas to reduce its velocity near these bends. But it is observed that the velocity of flue gases surprisingly increases near the lower bends as compared to upper ones. In this paper the authors have submitted the findings of analysis of finned tube economizer with Arresters at different inclinations. A steady 3D CFD tool is used for analysis and flow of the flue gases over the coils has been observed. The effect of provision of arresters on the surface temperature, the flue gas temperature, pressure and velocity field of fluid flow within an economizer tube using the actual boundary conditions have been analyzed using CFD tool. The analysis considered the inclination of Arresters both in upward and downward directions. The optimum dimensions of arresster and feasible inclination is recommended as a result of the study. The installation of Arresters, may affect the performance of economizer. The authors have analyzed the performance and tried to comment on this issue too.

Index Terms–boiler tube failure, erosion, Arresters and use

I.INTRODUCTION

The power plants are facing the problem of boiler tube leakage it is more critical when they are running on full load. It becomes one of the critical reasons among numerous reasons of the energy crisis. Utilities have been fighting boiler tube failure since long. The tube failure cost crores of rupees lost, as it causes loss in generation. Boiler tubes have limited life and can fail due to various failure mechanisms. Tube failures are classified as in-service failure in boilers. These failures can be grouped under six major causes:

1. Stress rupture
2. Fatigue
3. Water side corrosion
4. Erosion

5. Fire side corrosion

6. Lack of quality

It was found from the trends of failure for one of the thermal power plant in India that the economizer is the zone where the leakages are found more. The maximum number of cause of failure in economizer unit is due to erosion. Erosion is a process in which material is removed from the surface layers of an object impacted by a stream of abrasive particles.

Erosion of material depends on many factors; one of the important factors is 'Velocity'. The general equation for the same is as stated below:

$$\text{Erosion} = K * (\text{velocity})^n$$

Where, n = velocity exponent

k = Constant (Depends upon impact angle particle size and other parameters too)

Factors influencing fly ash erosion in coal fired boilers are

- The velocity of flue gas
- The temperature of flue gas
- The mineral content in coal
- The arrangement of pressure parts
- Deviation from design condition

Of these factors, the velocity of flue gas, the temperature of the flue gas and mineral matter in coal are the main influencing factors. Boiler tube failures continue to be the leading cause of forced outages in boilers. To get the boiler back on line and reduce or eliminate future forced outages due to tube failure, it is extremely important to determine and correct the root causes. CFD analysis of economizer can be useful to gain insight to the gas flow distribution. Efforts are made to measure the velocity and pressure distribution of flue gases at the bends of the economizer coil and serpentine strips also it will be useful to find the effect of the operating parameter on the tube erosion rate and velocity and pressure distribution inside the economizer. CFD has evolved as important tool for modeling of coal fired boiler and it can useful to quantify the gas flow field and temperature distribution with the boiler economizer. Hence Fluent6.3 was use to study the velocity and temperature distribution of the flue gases inside the economizer.

II. COMPUTATIONAL FLUID DYNAMICS ANALYSIS OF ECONOMISER UNIT USING FLUENT6.3.

These analysis are divided into four parts.

- CFD modeling of Economizer Zone.
- Flow of flue gases over Economizer tubes without Arresters.
- Flow of flue gases over Economizer tubes with horizontal Arresters.
- Flow of flue gases over Economizer tubes with inclined Arresters.
- Effect on the performance of Economizer.

A. CFD modeling of Economizer Zone.

The complete CFD modeling is divided into following three steps:

- Pre-Processing
- Solver
- Post-Processing

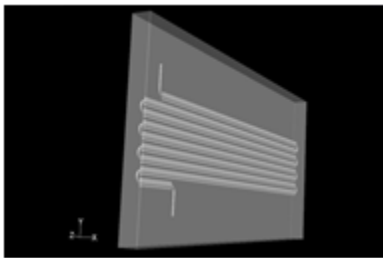


Fig.1 Flue Gas Domain Surrounding the Economizer Tube.

Assumptions for the CFD Analysis of Economizer Tube

- All the physical properties of the fluid and of the solid are considered as constant.
- Steady and turbulent flow of fluid.
- The flow enters at constant temperature and with uniform velocity.
- Model of turbulence adopted is $k-\epsilon$.

The model is drawn as per the actual geometry. The flue gas domain surrounds the economizer tube. All dimensions are actual. The Fig. 1 shows the economizer tube inside the flue gas domain. Flue gases are entering from the top, passing over the coil and leaving the domain from bottom face of the volume.

The above geometry is meshed using tetrahedral cells into 1294243 cells.

Solver - Boundary Conditions and Physical Models

(1) Flue Gas Inlet Conditions:

Flue Gas Inlet Temperature = 732 °K

Flue Gas Inlet Pressure = -362.97 Pa (g)

(2) Flue Gas Outlet Conditions:

Flue Gas Outlet Temperature = 641 K

Flue Gas Outlet Pressure = -529.74 Pa (g)

Calculation of Inlet Velocity:

Total mass flow rate = 910 T/hr. = 253 kg/sec.

C/S dimensions of economizer zone:

Width = 8.292 m, Depth = 13.86 m

Therefore mass flow rate per m^2 = 2.199 kg /sec.

Flue gas domain considered in modeling: W = 8.292 m,

Depth = 0.19325 m (spacing between adjacent tubes)

The mass flow rate through the domain = 3.524 kg /sec.

Now, $m = \rho \times \text{area} \times \text{velocity}$

Therefore, $3.524 = 1.225 \times 8.292 \times 0.19325 \times V$

Therefore, $V = 1.79$ m/sec.

Inlet Velocity of Flue Gases = 2.30 m/sec (From CAVT test results)

Therefore $V = 2.30$ m/sec is considered for the analysis.

Surface temperature of coil = 550 K

(3) Turbulence Model used = Standard k- Epsilon

B. Flow of flue gases over Economizer tubes without Arresters.

Our main focus is to find out temperature distribution along the tube coil in the critical zone and finding the region where the velocity exceed the limiting value which will be very much helpful in finding the critical area of tube failure and its reason. From Fluent velocity contour for Economizer, we found that the velocity is maximum at the U-bends because the flow area is reduced. Hence the erosion is more at this section of tubes. The different contours depending upon velocity and temperature are as follows:

Velocity Contour:

The Fig.2 shows the variation of flue gas velocity in m/s flowing over the tube. A considerable high velocity is found near u-tube bends. Flow velocity at other region is not much significant.

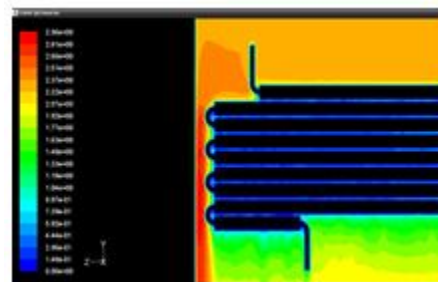


Fig.2 Velocity Contour

Velocity near bend 1 is found to be 2.735 m/s, near bend 2 is 2.885 m/s, near bend 3 is 2.995 m/s and near bend 4 is 2.995 m/s. Velocity of flue gas increases from upper bends to lower bends.

Temperature Contour:

Fig.3 shows the variation of static temperature over the finned tube economizer. Tube bend is found to be exposed to the high temperature region.

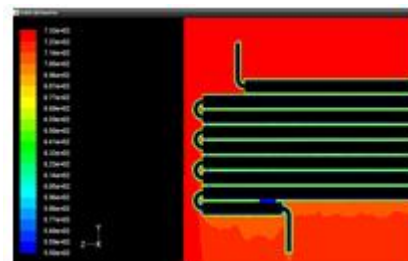


Fig.3 Temperature Contour

Temperature near bend 1 is found to be 727.5 K, near bend 2 is 727.5 K, near bend 3 is 727.5 K m/s and near bend 4 is 727.5 K m/s.

C. Flow of flue gases over Economizer tubes with horizontal Arresters.

The CFD result shows that the reason for the failure is the high temperature failure and ash particle erosion due to high temperatures and increase in velocity at the u bends in economizer.

As we know that:

$$\text{Erosion} = K * (\text{velocity})^n$$

Where, n = velocity exponent

k = Constant (Depends upon impact angle)

Thus the erosion rate increases with increase in flue gas velocity. So Arresters can be provided in the low area zones to prevent the direct impact of the flue gases on the boiler tubes. The flue gases will impinge on the Arresters, which will reduce its velocity, and the tubes will wear less due to reduced velocity of flue gases. The Fig.4 shows the height and width of Arresters. The following H and W values were used for the analysis:

H= 160, 180, 200, 220 mm and W= 60, 100, 140, 180 mm. For each value of H, the W was changed (e.g. H= 160mm, W=60, 100, 140, 180mm).

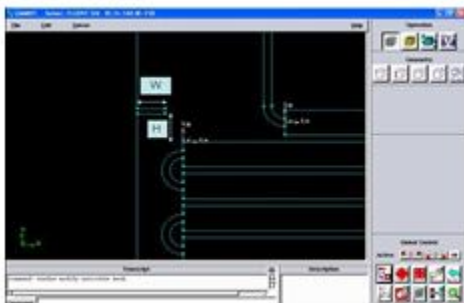


Fig.4 Height (H) above the coil and Width (W) of the Baffle

Likewise the analysis was carried for each height mentioned above. A detailed analysis with different Height - Width dimensions of arrester was done. Mr. Prasad Shivdas and Mr. Mahesh Zodge found that velocity of the flue gas was minimum at H = 160mm & W = 140 mm.

The different contours depending upon velocity and temperature by using horizontal arresters of above mentioned dimension are as follows.

Velocity Contour:

Fig.5 shows the velocity contour with the use of Arrester. From the contour below it is clear that the velocity is very much less than that of the velocity without using Arresters.

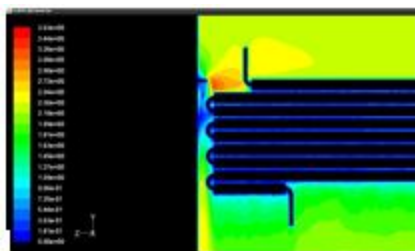


Fig.5 Velocity Contour

Velocity near bend 1 is found to be 0.8155m/s, near bend 2 is 0.8155 m/s, near bend 3 is 1.72 m/s and near bend 4 is 2.27 m/s

Temperature Contour:

Fig.6 shows the temperature contour with the use of Arrester.

From this temperature contour it is clear that by providing Arresters in the way of flue gas will not have any effect on zone temperature of the economizer. So, the heat transfer will not be affected by using the Arresters.

Temperature near bend 1 is found to be 727.5 K, near bend 2 is 727.5 K, near bend 3 is 727.5 K m/s and near bend 4 is 727.5 K m/s.

D. Flow of flue gases over Economizer tubes with inclined Arresters.

Initially the Arresters were placed horizontally and the inclination factor was not considered.

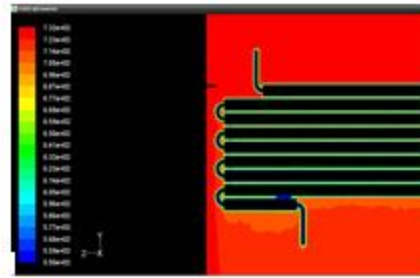


Fig.6 Temperature Contour

Now the analysis is done for the inclination (both in upward and downwards direction) between 0° – 45° in the interval of 5°.

Different combinations of Arrester width and inclination (downwards) were made and they are as follows:

1. Height (H) -160mm, Width (W) -140mm, 0o to 45o
2. Height (H)-160mm, Width (W)-180mm, 0o to 45o.
3. Height (H)-160mm, Width (W) -200mm, 0o to 45o
4. Height (H)-160mm, Width (W) -248mm, 0o to 45o .

Combinations of Arrester width and inclination (Upwards direction)

5. Height (H) -160mm, width (W) -140mm, 0° to 45°.

After performing the analysis for all these combinations, we found that as we increase the angle of the Arrester the velocity at the upper bends reduces but it start increasing in the lower bends. Hence, to know the detailed value of velocity at these U bends. We have divided these bends in to different zones as shown in the Fig.7.

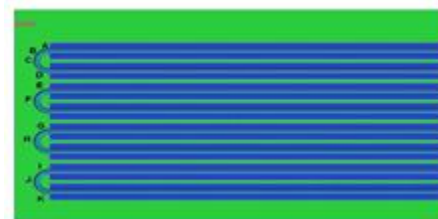


Fig.7 Different Zones for U-bends sections

- 1.For Height (H) -160mm, Width (W) -140mm, 0° to 45°

For Zone A, minimum velocity of flue gas is 2.27 m/s, which is for horizontal arrester. For rest of the inclined arresters the value of velocity in zone increases with the increase in inclination.

Zone B is most critical Zone as erosion is more in this zone compare to other zones. In zone B minimum velocity of flue gas is 1.475 m/s for arrester with 15° inclination. This value is nearly equal to the value of velocity for horizontal arrester which is 1.54 m/s. In this zone velocity is 2.44 m/s for without arrester zone.

For Zone C, minimum velocity of flue gas is 0.81 m/s, which is for horizontal arrester. Corresponding value of velocity in zone C without arrester is 2.375 m/s, which is comparatively more than the horizontal arrester value.

For Zone D, minimum velocity of flue gas is 0.4345 m/s, with arrester inclination of 15°. Corresponding value of velocity in zone D with horizontal arrester is 0.4535 m/s. Value of velocity without arrester is 2.295 m/s for this zone.

For Zone E, minimum velocity of flue gas with horizontal arrester is 0.8155 m/s. Corresponding value in this zone without arrester remains 2.295 m/s.

For Zone F, minimum velocity of flue gas is 0.8055 m/s with 20° inclined arrester. The value of velocity for horizontal arrester is 0.8155 m/s. For rest of the inclined arresters value of velocity varies in between 0.95 m/s to 0.99 m/s.

For Zone G, value for minimum velocity of flue gas for horizontal arrester is 0.8155 m/s and for rest of the inclined arresters the value varies in between 0.96 to 1.115 m/s. Corresponding value in this zone without arrester remains 2.44 m/s.

For Zone H, Zone I and Zone J, minimum value of velocity is for 45° inclined arrester. Velocities of flue gas are 1.51 m/s, 1.3 m/s, 2.045 m/s respectively. But for 45° inclined arrester the value of velocities at the upper zones are very high. For these zones the value of velocities for horizontal arrester are 1.72 m/s, 1.36 m/s, 2.2 m/s respectively. Values of velocity without arrester are 2.995 m/s, 2.44 m/s, 2.995 m/s respectively.

For Zone K, minimum velocity of flue gas is 1.475 m/s with arrester inclination of 15°. Value of velocity with horizontal arrester and without arrester are 1.54 m/s and 2.44 m/s respectively.

2. For Height (H)-160mm, Width (W)-180mm, 0° to 45°

For Zone A, Zone D and Zone F, minimum velocity of flue gas with 10° inclination of arrester are 1.395 m/s, 0.279 m/s, 0.466 m/s respectively.

Minimum velocity of flue gas remains at 0.46 m/s for Zone B and the same is 0.828 m/s for Zone G with 25° inclination of arrester.

For Zone C, Zone E, Zone H, Zone I and Zone J, minimum velocities of flue gas is for 40° inclination of arrester are 0.273 m/s, 1.005 m/s, 0.82 m/s, 1.005 m/s, 1.55 m/s respectively.

For Zone K, minimum velocity is 1.375 m/s, when arrester is at inclination of 45°.

3. For Height (H)-160mm, Width (W)-200mm, 0° to 45°

For Zone A, minimum velocity of flue gas is 0.862 m/s, which is for 5° inclined arrester.

For Zone B, Zone C, Zone H, Zone I and Zone K, minimum velocity of flue gas for 40° inclined arrester are 0.2715 m/s, 0.2715 m/s, 0.8135 m/s, 0.992 m/s, 1.36 m/s respectively.

For Zone D, minimum velocity is 0.278 m/s, which is for 20° inclined arrester.

For Zone E, minimum velocity is 0.8515 m/s, which is for 45° inclined arrester.

For Zone F, minimum velocity is 0.288 m/s which, is for horizontal arrester.

For Zone G and Zone J, minimum velocities for 30° inclined arrester are 0.5105 m/s, 1.55 m/s respectively

4. For Height (H)-160mm, Width (W)-248mm, 0° to 45°

Similarly the analysis was also done for this combination and the results were discussed. We can conclude from the above three combinations that with increase the width of the Arrester the flow passage near these bends reduces and because of which the flow of flue gases will also reduced (Fig. 8). This reduction of flue gases near these bends areas may affect the heat transfer rate and may cause drop in feed water temperature by few degrees.

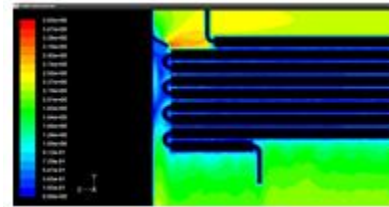


Fig.8 Velocity contour for w= 200 mm and inclination 30° : Possibility of no flow of flue gas over the bends

5. For Height (H)-160 mm, width (W)-140mm, 0° to 45° Upward inclination

Similar analysis was conducted to see the effect of arresters with upward inclination. It was observed that velocity reduction is less with upward inclination as compared to horizontal arresters..

Hence after comparing the results from all above combinations, we conclude that horizontal arrester of height (H) = 160mm and width (W) = 140mm reduces velocity of flue gas without affecting heat transfer process. Therefore may reduce the erosion.

E. Effect on the performance of Economizer.

Due to the installation of arrester, the effect can take place in U-bend section of the tube, where heat transfer may decrease. This in turn, can affect the overall outlet temperature of the economizer.

For without arrester value of temperature near bend 1 is found to be 727.5 K, near bend 2 is 727.5 K, near bend 3 is 727.5 K m/s and near bend 4 is 727.5 K m/s.

From the Fig.3 and Fig.6. It is clear that by the installation of Arresters in the way of flue gas will not affect the temperatures near the U-bends

And for with horizontal arrester of H=160mm , W=140mm value of temperature near bend 1 is found to be 727.5 K, near bend 2 is 727.5 K, near bend 3 is 727.5 K m/s and near bend 4 is 727.5 K m/s.

Hence, thus the heat transfer may not affect by the installation of Arresters.

III CONCLUSION

The erosion due to flue gas (Fly ash) is playing major role in boiler tube leakages. So, it is very necessary to reduce the erosion and indirectly reduction in breakdown time. CFD is a useful tool to show that the reason for the failure may be due to erosion caused by high velocity ash particle at the U bends in economizer. Arresters are found useful for reducing the erosion rate. Arresters provided at height of 160 mm and having width of 140 mm reduce the velocity

the most without affecting the heat transfer. Hence reduces the erosion. Horizontal Arresters are more effective than that of the inclined Arresters. The proposed onsite experimentation with the help of sacrificing specimen will validate the finding of the study.

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